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(54) **CONTROLLER FOR DATA RECORDER**

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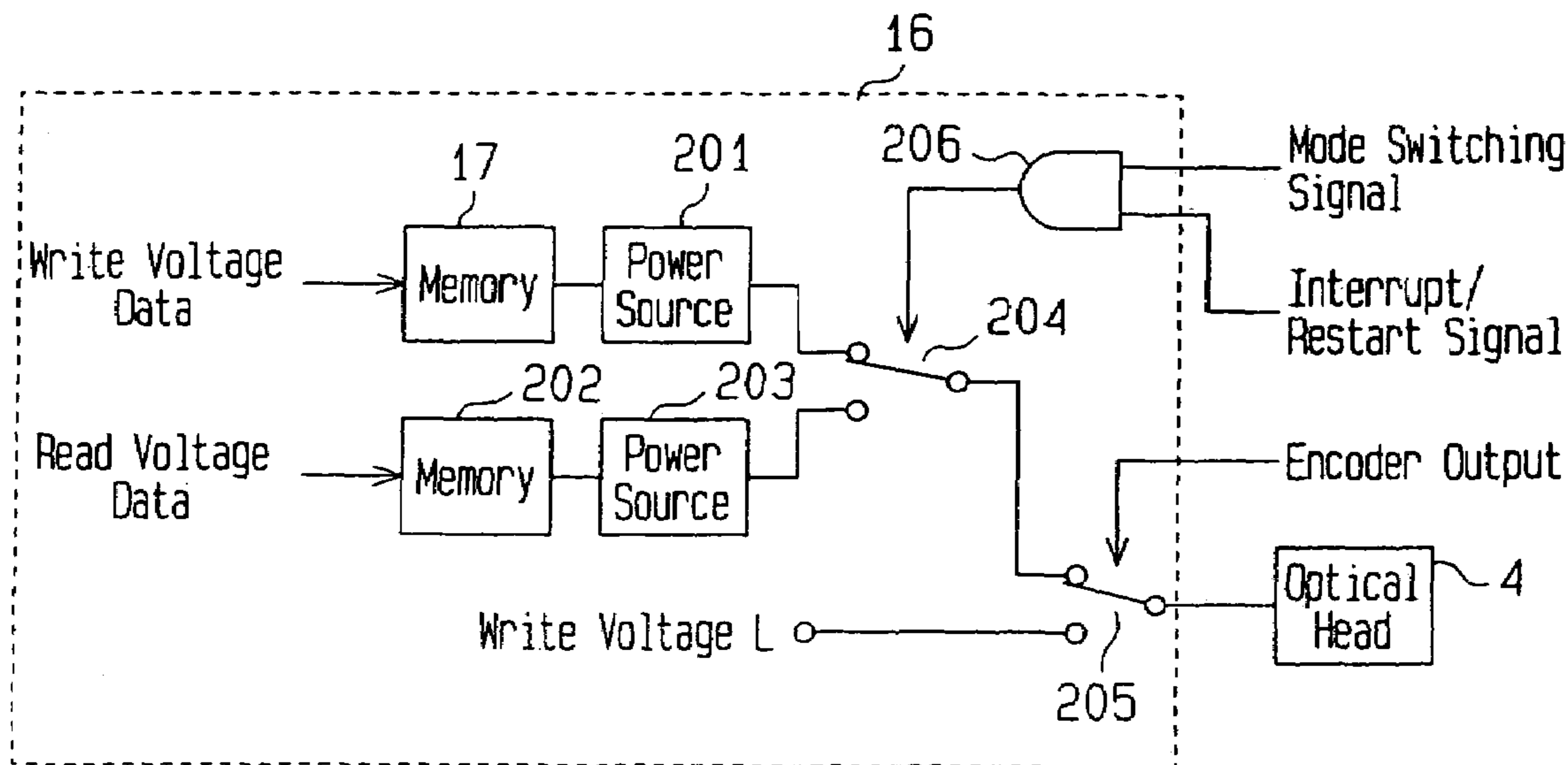
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(57) **ABSTRACT**

A controller for controlling interruptions and restarts when writing data to a recording medium by emitting a laser beam against the recording medium. The controller prevents buffer underrun errors. The laser beam is emitted at a high power level when writing data on the recording medium and at a low power read level when reading data from the medium. The writing of data is interrupted when there is a possibility of a buffer underrun error. When restarting data writing from where the interruption occurred, the laser beam is shifted from the read level to the write level before reaching the location at which the interruption occurred. This guarantees that the laser beam has the required power level when writing is restarted.

**8 Claims, 3 Drawing Sheets**



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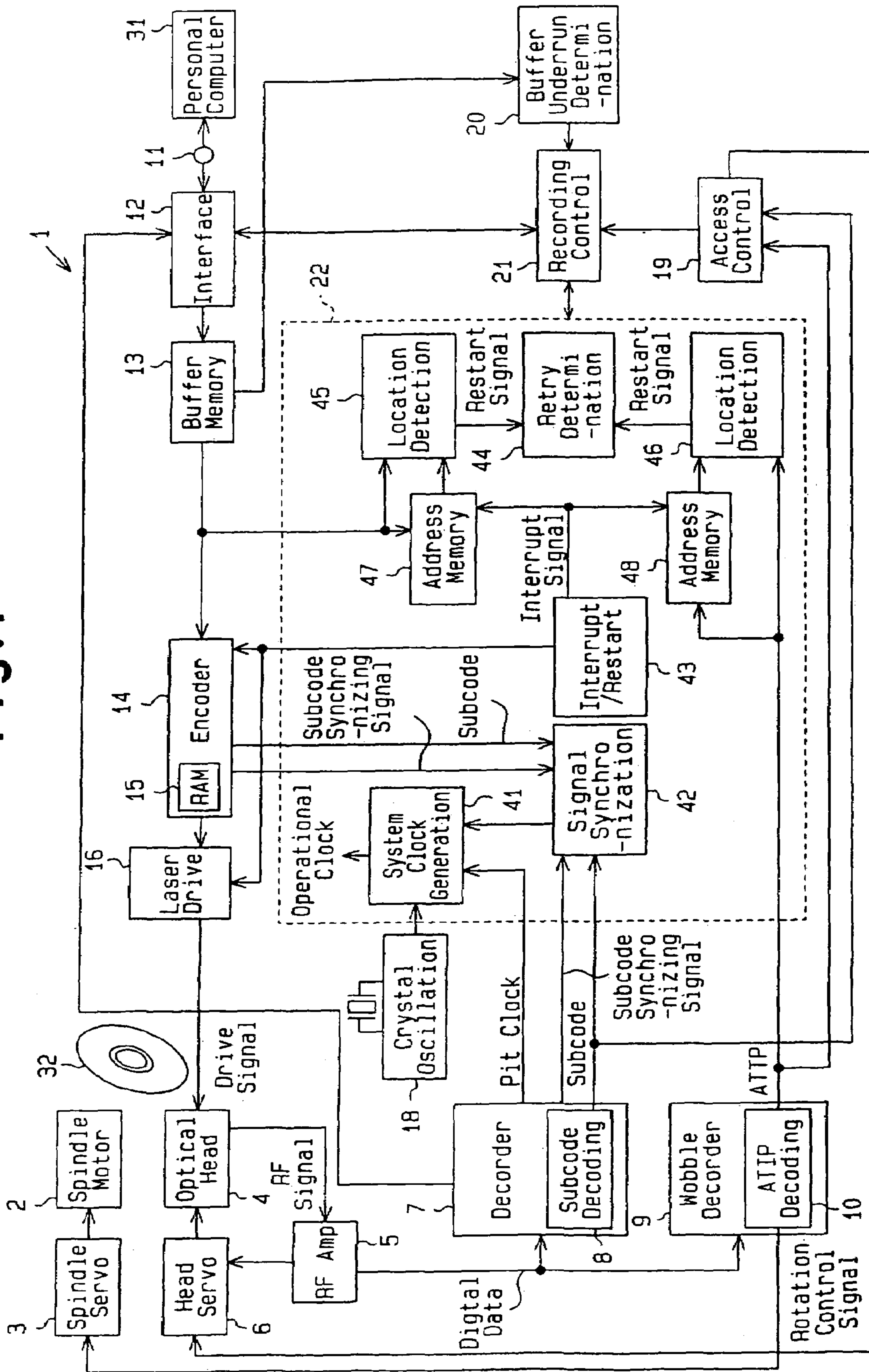
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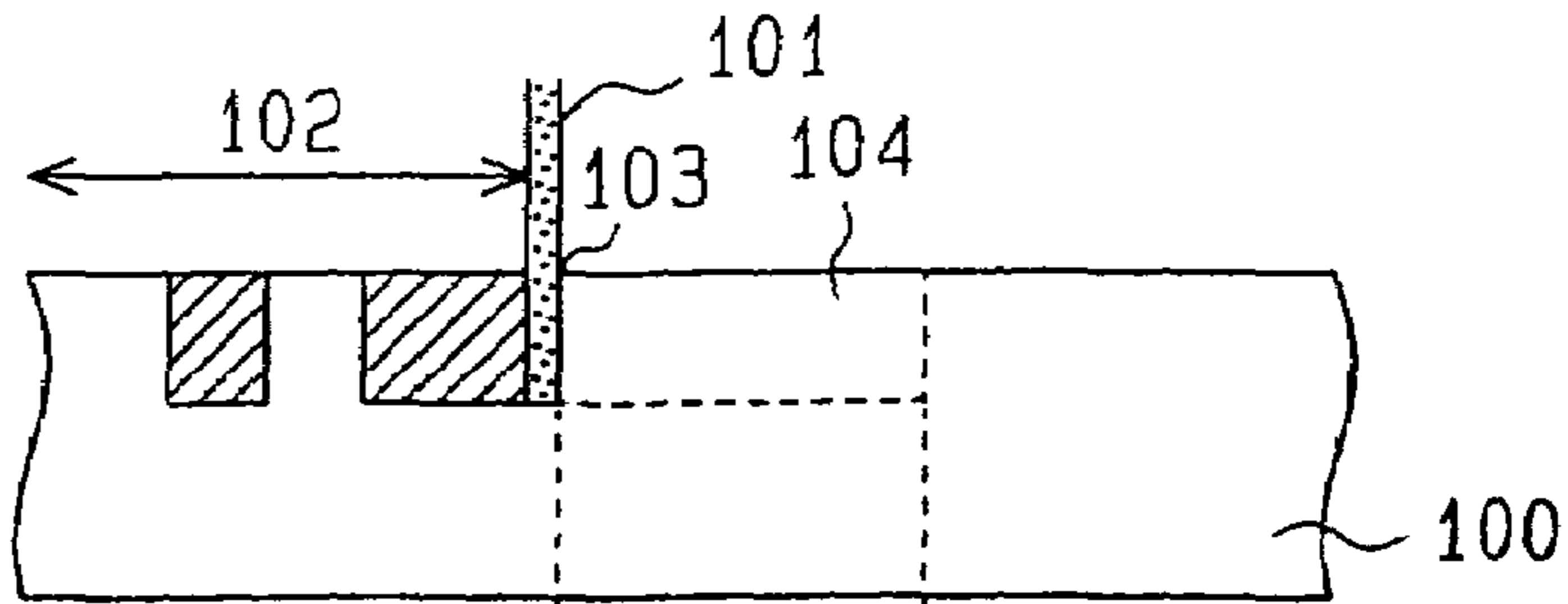
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Fig. 1

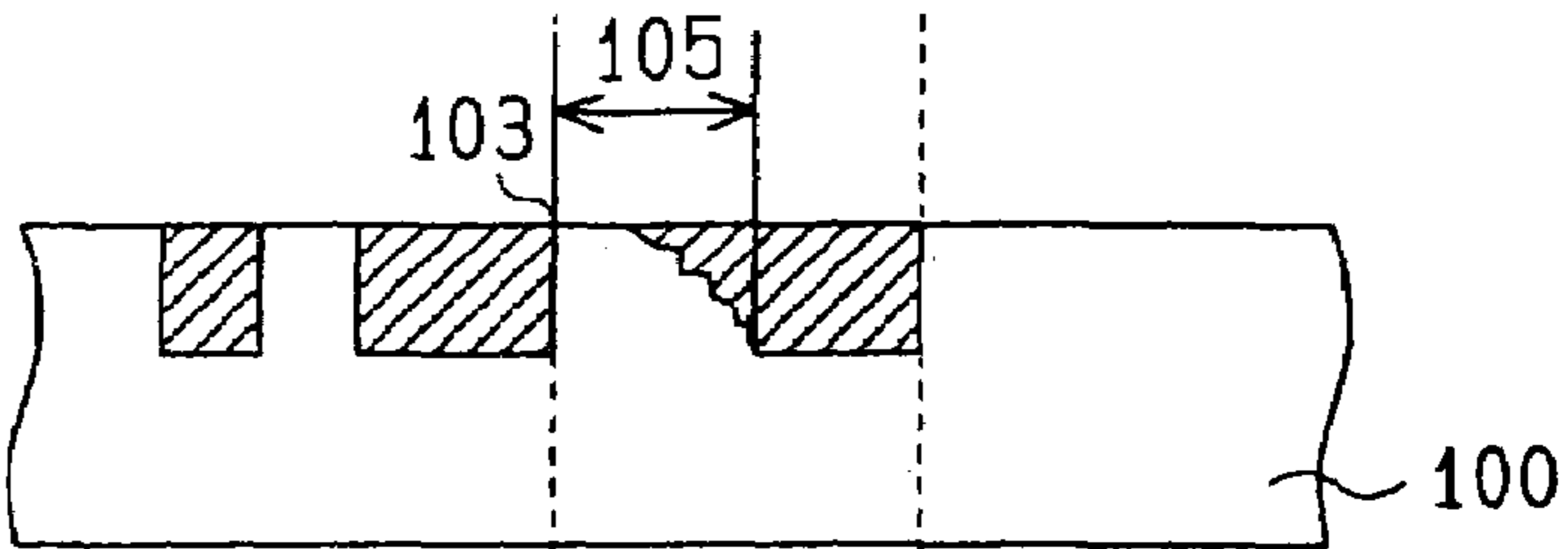




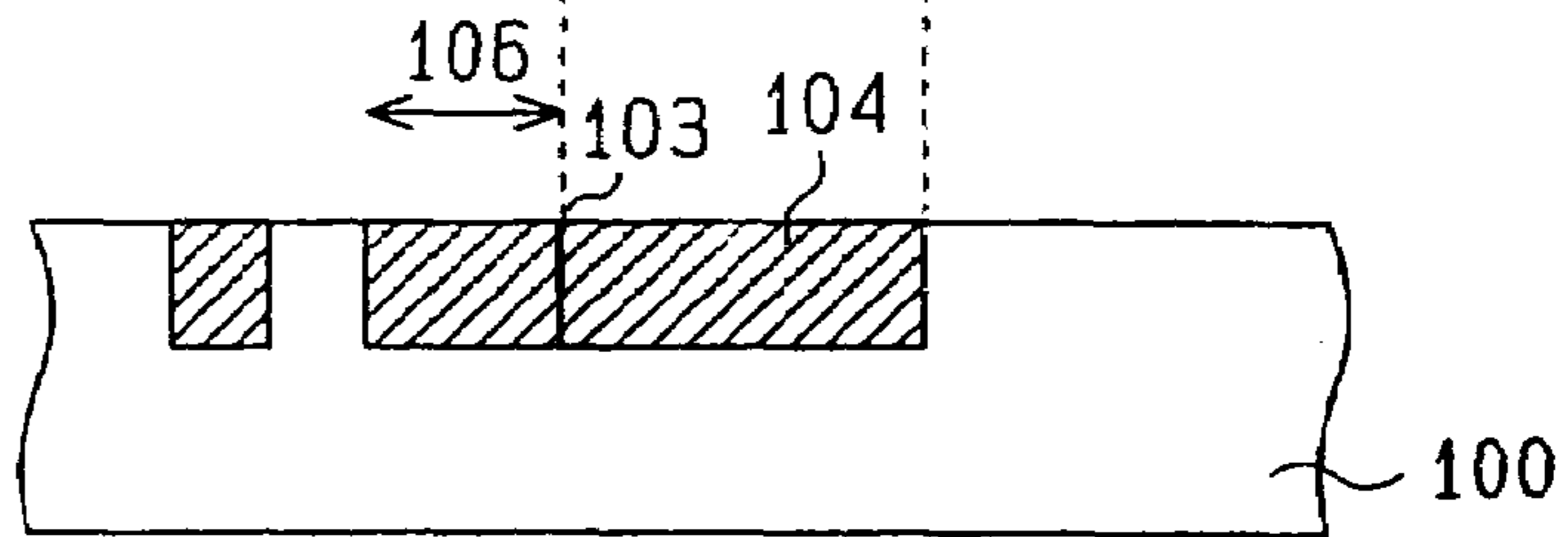
**Fig. 2 (a)**



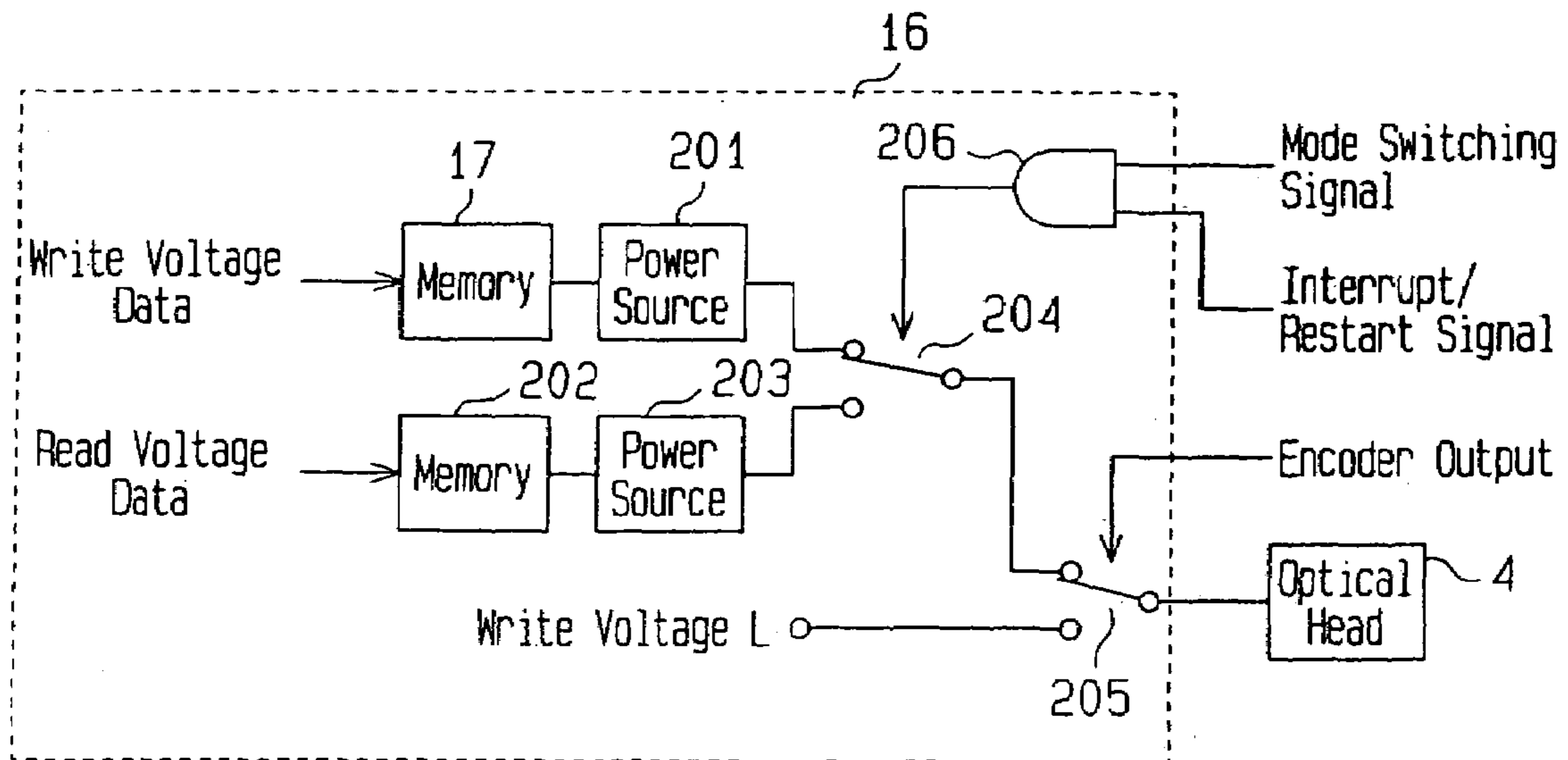
**Fig. 2 (b)**



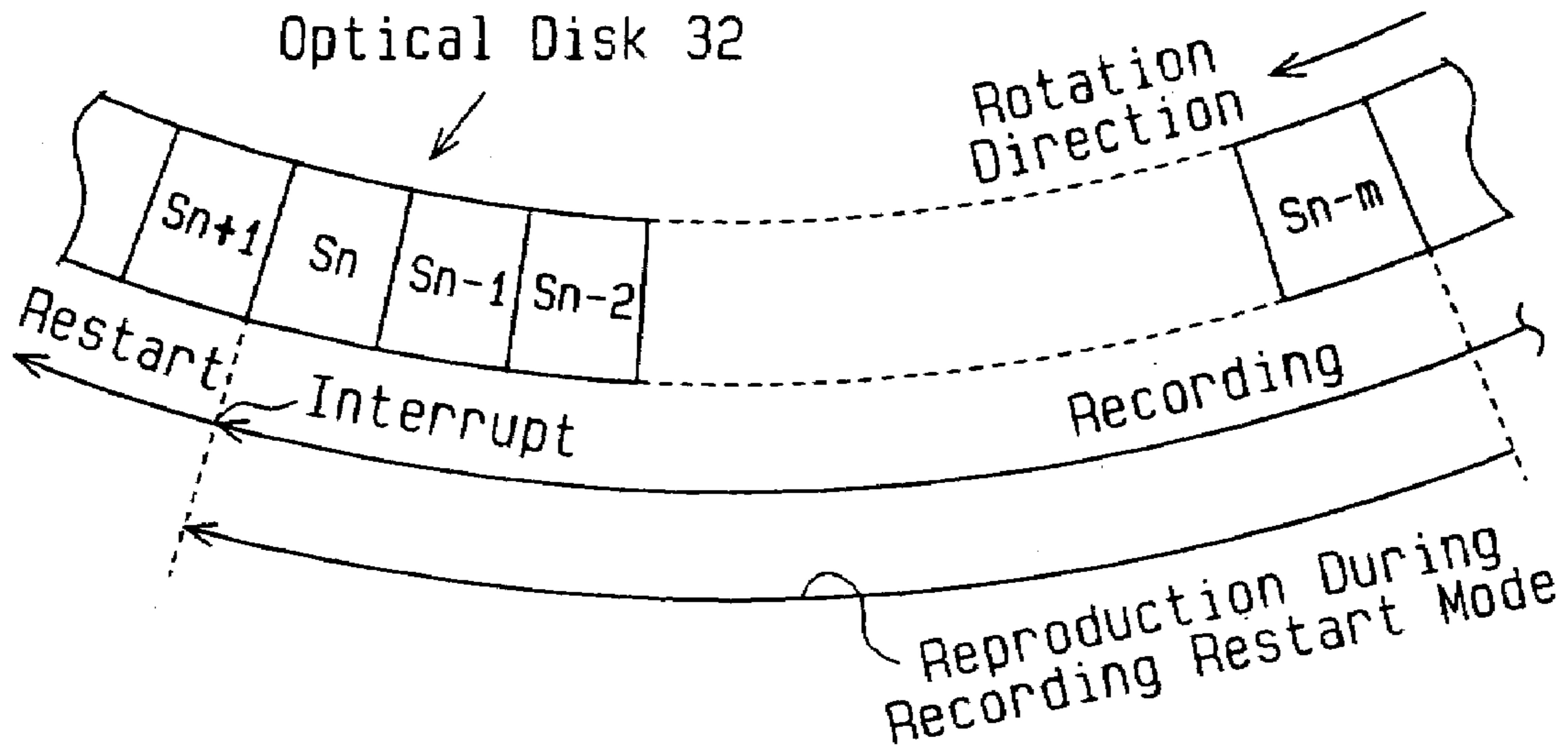
**Fig. 2 (c)**



**Fig. 3**

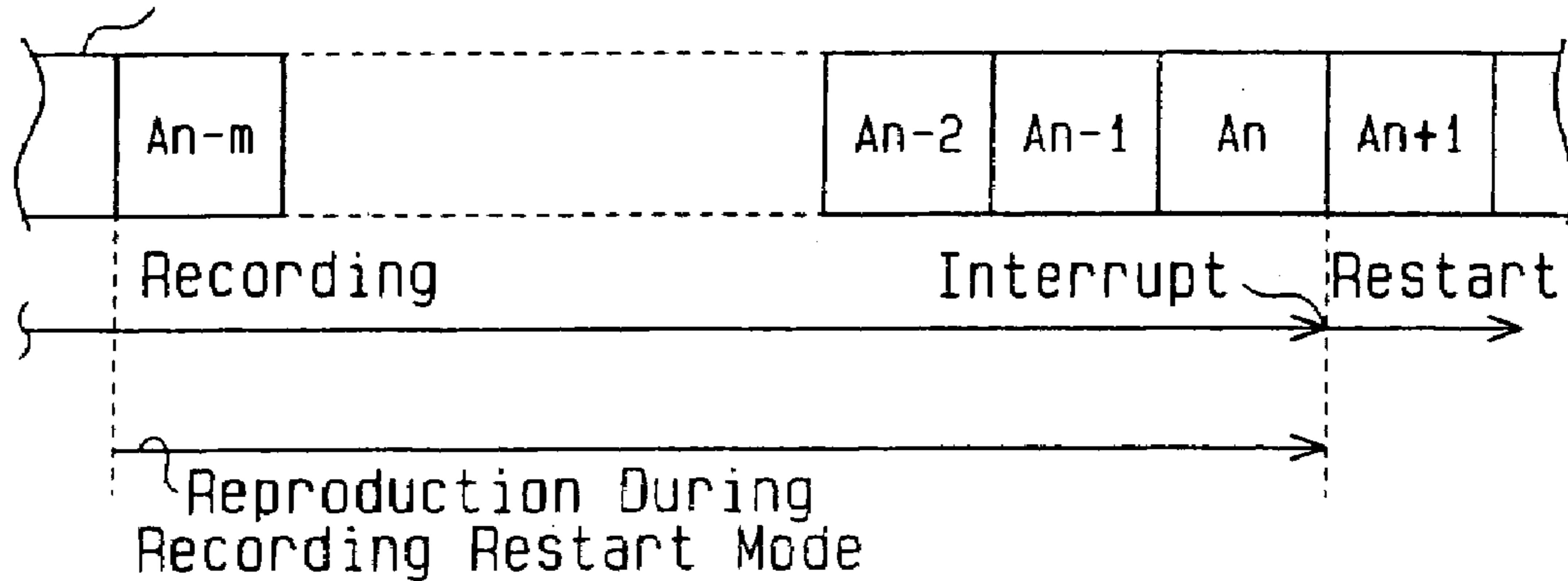


### Fig.4(a)



### Fig.4(b)

Buffer Memory 13





**CONTROLLER FOR DATA RECORDER**

## RELATED APPLICATIONS

This application is a continuation and claims the benefit of 5 priority under 35 USC 120 of U.S. application Ser. No. 09/718,155, filed Nov. 21, 2000. The disclosure of the prior application is considered part of and is incorporated by reference in the disclosure of this application. This applica- 10 tion also claims the benefit of priority under 35 USC 119 of Japanese application serial numbers 11-331418, filed Nov. 22, 1999 and 2000-322074, Filed Oct. 23, 2000.

## BACKGROUND OF THE INVENTION

The present invention relates to a data recorder, and more particularly, to a controller for a data recorder having a buffer memory for storing data provided from an external device and recording the stored data of the buffer memory on a recording medium.

An optical disc recorder records data on an optical disc, which serves as a recording medium. A CD-DA family compact disc-recordable (CD-R) drive is one type of optical disc recorder that is widely used. A CD-R is a so-called write-once optical disc on which data is written only once. 25 The recorded data cannot be physically deleted. A laser beam is irradiated against the optical disc from an optical head of the CD-R drive. The heat of the laser beam melts a dye and forms recording pits on a recording layer of the optical disc. Data is recorded on the disc by changing the reflecting rate of the recording layer.

The optical disc recorder includes a buffer memory and an encoder. The buffer memory temporarily stores data provided from an external device, such as a personal computer. The encoder reads the data from the buffer memory and encodes the read data to record the data on the optical disc. 35

In such an optical disc recorder, if, for example, the rate of data transmission from the external device is slower than the recording data transmission rate of the optical disc (write speed), the transmission rate of the recording data output 40 from the encoder is faster than the transmission rate of the data provided to the buffer. This decreases the amount of data stored in the buffer memory. If the decrease continues, the data amount ultimately becomes null and the buffer memory becomes empty. This stops the stream of data to the encoder and causes an interruption in the data recorded on the optical disc. This problem is referred to as buffer underrun. The interruption in the data recorded on the optical disc resulting from buffer underrun is referred to as a buffer underrun error.

Data is recorded on an optical disc using a recording technique that designates the file group recorded on the optical disc (e.g., disc at once, track at once). Thus, if a buffer underrun error occurs, the entire optical disc becomes unusable when employing disc at once, and the track under- 55 going recording becomes unusable when employing track at once.

Recent CD-R drives record data at a speed four times or eight times the normal recording speed. Further, recent personal computers have multitasking functions to operate 60 CD-R drives. This has increased the tendency of the occurrence of buffer underrun errors.

Packet writing is one type of data recording that records data in packet units. Packet writing records data on an optical disc when the data reaches the capacity of the packet. 65 This prevents the occurrence of buffer underrun errors. However, link blocks must be formed to connect packets in

packet writing. The link blocks decrease the recording capacity of the optical disc. Further, there are CD-ROM drives that are not capable of handling packet writing. Such CD-ROM drives cannot reproduce data written to optical discs through packet writing. In other words, the CD-ROM compatibility required by the CD-R standard (Orange Book Part II) does not include packet writing. For example, packet writing cannot be applied for a CD-DA player. Thus, a CD-R drive cannot record CD-DA audio data through packet writing. Accordingly, there is a need for preventing buffer underrun errors without employing packet writing.

A CD-rewritable (CD-RW) drive is another type of optical disc recorder that is widely used. A CD-RW drive irradiates a laser beam from an optical head against an optical disc. 15 The heat of the laser beam causes phase changes between amorphous and crystalline to form recording pits on the recording layer of the optical disc. This changes the reflecting rate of the recording layer and records data on the optical disc. Data can be repeatedly rewritten to optical discs used by the CD-RW drive. Accordingly, the optical disc remains 20 usable even if a buffer underrun error occurs. However, when a buffer underrun error occurs, the data file that was being recorded before the occurrence of the buffer underrun error must be recorded again. This wastes the recording performed prior to the occurrence of the buffer underrun error and increases the recording time.

A magneto-optic disc recorder is another type of known data recorder. The magneto-optic disc recorder irradiates a laser beam from an optical head against a magneto-optic disc. This applies residual magnetization to the recording layer of the optical disc and records data on the magneto-optic disc. Mini disc (MD) drives are widely used magneto-optic disc recorders. However, MD drives have the same problem as CD-RW drives. 30

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a controller for a data recorder that controls data recording in a manner that the continuity of the data is ensured even if the recording of data to a recording medium is interrupted.

To achieve the above object, the present invention provides a controller for controlling interruption and restarting data writing to a recording medium. The data writing is performed by emitting a laser beam against the recording medium at a write level that is in accordance with data read from a buffer memory. The controller includes an address memory for storing at least one of an address of the recording medium and an address of the buffer memory 45 when the writing of data to the recording medium is interrupted. Each address indicates a data location where the writing interruption occurred. A synchronizing circuit reads the data written to the recording medium prior to the interruption by emitting the laser beam at a read level, reading the data stored in the buffer memory, and synchronizing the written data and the stored data. A restart circuit restarts the data writing based on the address stored in the address memory. The restart circuit switches the laser beam from the read level to the write level before the restart circuit restarts the data writing. 50

A further aspect of the present invention provides a controller for controlling interruption and restarting data writing to a recording medium. The data writing is performed by emitting a laser beam against the recording medium in accordance with data read from a buffer memory. The controller includes an address memory for storing at least one of an address of the recording medium and an 65



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address of the buffer memory when the writing of data to the recording medium is interrupted. Each address indicates a location of data when the writing interruption occurred. A synchronizing circuit reads the data written to the recording medium prior to the interruption by emitting the laser beam, reads the data stored in the buffer memory, and synchronizes the written data and the stored data. A restart circuit generates an instruction for restarting the writing of data to the recording medium based on the address stored in the address memory. The restart circuit generates the instruction for restarting the writing of data before the data read from the recording medium by the synchronizing circuit reaches the interruption location.

Another aspect of the present invention provides a controller for controlling interruption and restarting data writing to a recording medium. The data writing is performed by emitting a laser beam against the recording medium with a power that is in accordance with data read from a buffer memory and supplied from a power source. The controller includes an address memory for storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted. Each address indicates a data location where the writing interruption occurred. A synchronizing circuit reads the data written to the recording medium prior to the interruption by emitting the laser beam, reads the data stored in the buffer memory, and synchronizes the written data and the stored data. A restart circuit restarts data writing based on the address stored in the address memory. The power source is activated prior to the time when the writing of data is restarted.

A further aspect of the present invention provides a method for controlling interruption and restarting of writing data to a recording medium. The data writing is performed by emitting a laser beam against the recording medium at a write level that is in accordance with data read from a buffer memory. The method includes storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted. Each address indicates a data location where the writing interruption occurred. The method further includes reading the data written to the recording medium prior to the writing interruption by emitting the read level laser beam against the recording medium and reading the data stored in the buffer memory, synchronizing the written data and the stored data, generating an instruction for restarting data writing to the recording medium based on the address stored in the address memory, and shifting the laser beam from the read level to the write level before writing is restarted.

Another aspect of the present invention provides a method for controlling interruption and restarting of data writing to a recording medium. The data writing is performed by emitting a laser beam against the recording medium in accordance with data read from a buffer memory. The method includes storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted. Each address indicates a data location where the writing interruption occurred. The method further includes reading the data written to the recording medium prior to the writing interruption by emitting the laser beam against the recording medium and reading the data stored in the buffer memory, synchronizing the written data and the stored data, and generating an instruction for restarting data writing based on the address stored in the address memory. The

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writing is restarted before the location of the data read from the recording medium in the reading step reaches the interruption location.

A further aspect of the present invention provides a method for controlling interruption and restarting data writing to a recording medium. The data writing is performed by emitting a laser beam against the recording medium at a power level that is in accordance with data read from a buffer memory and supplied from a power source. The method includes storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted. Each address indicates a data location where the writing interruption occurred. The method further includes reading the data written to the recording medium prior to the writing interruption by emitting the laser beam and reading the data stored in the buffer memory, synchronizing the written data and the stored data, generating an instruction for restarting the writing of data to the recording medium based on the address stored in the address memory, and activating a power source for generating power of the laser beam prior to the restart of the writing of data.

Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a schematic block diagram showing a CD-R drive according to a preferred embodiment of the present invention;

FIG. 2(a) is a schematic cross-sectional view showing a recording medium during the interruption of data recording;

FIG. 2(b) is a schematic cross-sectional view showing the recording medium when a laser is activated from an interrupt position to restart the data recording;

FIG. 2(c) is a schematic cross-sectional view showing the recording medium when the laser is activated before the laser reaches the interrupt position to restart the data recording;

FIG. 3 is a schematic block diagram showing a laser drive circuit of the CD-R drive of FIG. 1;

FIG. 4(a) is a schematic diagram showing a sector of an optical disc; and

FIG. 4(b) is a diagram illustrating addresses of a buffer memory of the CD-R drive of FIG. 1.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, a CD-R drive 1 includes a spindle motor 2, a spindle servo circuit 3, an optical head 4, an RF amplifier 5, a head servo circuit 6, a decoder 7, a subcode decoding circuit 8, a wobble decoder 9, an ATIP decoding circuit 10, an external connection terminal 11, an interface 12, a buffer memory 13, an encoder 14, an encoder internal RAM 15, a laser drive circuit 16, a laser drive circuit internal memory (level memory) 17, a crystal oscillation circuit 18, an access control circuit 19, a buffer underrun determination circuit 20, a recording control circuit 21, and a system control circuit 22. The CD-R drive 1 is connected to a personal computer 31 via the external connection



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terminal 11 to record data, which is provided from the personal computer 31, on an optical disc 32 that complies with the CD-R standards. Further, the CD-R drive 1 provides the personal computer 31 with data reproduced from the optical disc 32.

The spindle motor 2 rotates the optical disc 32. The spindle servo control circuit 3 controls the spindle motor 2 so that the optical disc 32 is rotated using the constant linear velocity (CLV) method in accordance with the rotation control signal generated by the wobble decoder 9.

When reading data, the optical head 4 irradiates a relatively weak laser beam against the optical disc and, from the reflected laser beam, generates a RF signal (high frequency signal) in correspondence with the data recorded on the optical disc. When recording data, the optical head 4 irradiates a relatively intense laser beam (several tens of times greater than the data reading laser beam) against the optical disc 32 to form recording pits on the recording layer of the optical disc 32 and change the reflecting rate of the recording layer to record data. In synchronism with the recording of data, the optical head 4 generates the RF signal in correspondence with the recorded data from the reflected laser beam.

The RF amplifier 5 amplifies the RF signal, which is provided from the optical head 4, and digitizes the amplified RF signal to generate a digital data signal. The RF signal of the optical head 4 is fed back to the head servo circuit 6 via the RF amplifier 5. The head servo circuit 6 uses the RF signal to perform focusing control, tracking control, and sled feed control. Focusing control focuses the laser beam on the recording layer of the optical disc 32. Tracking control tracks the laser beam along a signal track of the optical disc 32. Sled feed control moves the optical head 4 in the radial direction of the optical disc 32.

The decoder 7 decodes the digital data provided from the RF amplifier 5. Further, the decoder 7 generates a pit clock from the digital data and separates a subcode from the digital data to generate a subcode synchronizing signal.

The subcode decoding circuit 8, which is incorporated in the decoder 7, decodes the subcode. Further, the subcode decoding circuit 8 generates subcode Q channel data (hereafter referred to as sub-Q data) from the decoded subcode.

The wobble decoder 9 extracts a wobble component of 22.05 kHz from a pre-groove signal of the optical disc 32 that is included in the digital data provided from the RF amplifier 5. Then the wobble decoder generates the rotation control signal of the optical disc 32 from the wobble component.

The ATIP decoding circuit 10, which is incorporated in the wobble decoder 9, uses the wobble component to decode an absolute time in pre-groove (ATIP) and extract absolute time information, or an ATIP address, from the ATIP. The absolute time information indicates addresses of locations in the recording medium.

The interface 12 controls data transmission between the personal computer 31 and the CD-R drive 1.

The buffer memory 13 is a ring buffer that includes a synchronous dynamic random access memory (SDRAM), which preferably has a FIFO configuration, and the buffer memory 13 stores data provided from the personal computer 31 via the interface 12. Data stored at one address of the buffer memory 13 corresponds to data recorded at one sector of the optical disc 32.

An interrupt/restart circuit 43 of the system control circuit 22 controls the encoder 14. The encoder 14 reads the data stored in the buffer memory 13 in sector units and encodes the data into recording data for the optical disc 32. The RAM

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15, which is incorporated in the encoder 14, stores the necessary data for encoding by the encoder 14 and intermediate operation encoding data. When performing data encoding in compliance with the CD-ROM standard, the encoder 14 adds a synch byte, a header, CD-ROM data error detection code (EDC), and an error correction code (ECC) to the data. The encoder 14 further performs error correction using a cross interleaved Reed-Solomon code (CIRC), which is a CD error correction code, and eight to fourteen modulation (EFM) on the data. Further, the encoder 14 adds a subcode, which includes the sub-Q data, and a synchronizing signal of the subcode to the data.

The interrupt/restart circuit 43 also controls the laser drive circuit 16, which provides a laser drive signal to the laser beam source of the optical head 4. The laser drive circuit internal memory 17 stores data related to the voltage of the laser drive signal output from the laser drive circuit 16. The voltage of the drive signal is constant when reproducing data and varied in accordance with the recording data output from the encoder 14 when recording data. When the recording data output from the encoder 14 is low (L), recording pits are not formed on the recording layer of the optical disc 32. Thus, the drive signal is set so that its voltage is the same as when data is reproduced. When the recording data is high (H), recording pits are formed on the recording layer of the optical disc 32. Thus, although the voltage of the drive signal differs between track positions, the drive signal is set so that its voltage is several tens of times greater than during data reproduction.

The crystal oscillation circuit 18 generates an oscillation signal based on the oscillation of a crystal oscillator.

The access control circuit 19 selectively refers to the subcode address of the absolute time information in the sub-Q data and the ATIP address of the absolute time information in the ATIP to control the recording control circuit 21 and the head servo circuit 6. This controls access to the optical disc 32.

The data provided to the buffer memory 13 is stored in the buffer memory 13 in a predetermined address order. The buffer underrun determination circuit 20 directly or indirectly determines the amount of data stored in the buffer memory 13 from the address at which writing or reading is presently performed. Based on the data amount, the buffer underrun determination circuit 20 determines whether or not the buffer memory 13 is in a state in which buffer underrun may occur.

Based on the determination result of the buffer underrun determination circuit 20 and in response to a command provided from the personal computer 31, the recording control circuit 21 controls the interface 12, the access control circuit 19, and the system control circuit 22.

The system control circuit 22 includes a system clock generation circuit 41, a signal synchronizing circuit 42, the interrupt/restart circuit 43, a retry determination circuit 44, location detection circuits 45, 46, and address memories 47, 48. These circuits 41–48 are laid out on the same chip of an LSI substrate.

The system clock generation circuit 41 generates from the oscillation signal of the crystal oscillation circuit 18 a reference clock used when recording data. Further, the generation circuit 41 uses a pit clock extracted by the decoder 7 to generate a reproduction clock used when reproducing data. The generation circuit 41 selects the reference clock or the reproduction clock in accordance with the switching control performed by the signal synchronizing circuit 42. The selected clock is used as a system operational clock of the CD-R drive 1. In accordance with the opera-



tional clock, the CD-R drive 1 controls the synchronization of the circuits 7–10, 12–16, and 19–22.

In accordance with the synchronizing signal of the subcode from the decoder 7 and the sub-Q data from the subcode decoding circuit 8, the signal synchronizing circuit 42 controls the recording control circuit 21 so that the recording data output from the encoder 14 is synchronized with the data recorded on the optical disc 32. When performing this control, the sub-Q data of the subcode decoding circuit 8 is associated with the sub-Q data of the encoder 14 after synchronizing the subcode synchronizing signal of the decoder 7 with the subcode synchronizing signal of the encoder 14. The signal synchronizing circuit 42 controls the system clock generation circuit 41 so that the reference clock or the reproduction clock is output.

The recording control circuit 21 controls the interrupt/restart circuit 43. The interrupt/restart control circuit 43 controls the encoder 14 and the laser drive circuit 16 and, when the buffer underrun determination circuit determines that the buffer memory 13 has entered a state in which buffer underrun may occur, provides the address memories 47, 48 with a recording interrupt signal.

The address memory 47 stores the address of the read data in the buffer memory 13 when receiving the recording interrupt signal from the interrupt/restart circuit 43.

The address memory 48 stores the address of the ATIP decoded by the ATIP decoding circuit 10 when receiving the recording interrupt signal from the interrupt/restart circuit 43.

When data is reproduced during a recording restart mode (described later), the location detection circuit 45 compares the address of the data read from the buffer memory 13 with the address stored in the address memory 47. If the data address and the stored address are the same, the location detection circuit 45 activates the recording restart signal.

When data is reproduced during the recording restart mode, the location detection circuit 46 compares the address of the ATIP decoded by the ATIP decoding circuit 10 with the ATIP address stored in the address memory 48. If the decoded ATIP address and the stored ATIP address are the same, the location detection circuit 46 activates the recording restart signal.

The retry determination circuit 44 instructs the recording control circuit 21 to restart the recording operation of the interface 12, the access control circuit 19, and the system control circuit 22 when the restart signals of the location detection circuits 45, 46 are simultaneously activated. When the two restart signals are not synchronously activated (when the restart signals are activated at different timings), the retry determination circuit 44 instructs the control circuit 21 to repeatedly perform data reproduction in the recording restart mode until the two restart signals are synchronously activated.

The operation of the CD-R drive 1 will now be discussed.

When a user manipulates the personal computer 31 to record data, the personal computer 31 generates a command accordingly. The command is transferred to the recording control circuit 21 via the interface 12. In response to the command, the recording control circuit 21 controls the interface 12, the access control circuit 19, and the system control circuit 22 to record data.

When recording begins, the signal synchronizing circuit 42 switches the operational clock output of the system clock generation circuit 41 to the reference clock. As a result, the circuits 7–10, 12–16, 19–22 of the CD-R drive 1 are synchronized with the operational clock, or the reference clock.

The data provided from the personal computer 31 is stored in the buffer memory via the interface 12 and read from the buffer memory 13 in sector units. The encoder 14 encodes the data read from the buffer memory 13 in sector units to generate recording data. The laser drive circuit 16 provides the optical head 4 with drive signal having a voltage corresponding to the recording data. In accordance with the drive signal, the optical head 4 changes the intensity of the laser beam irradiated against the optical disc 32. This forms recording pits on the recording layer of the optical disc 32 and records data on the optical disc 32. Simultaneously, from the laser beam reflected by the optical disc 32, the optical head 4 reproduces the data recorded on the optical disc 32 as the RF signal. The RF amplifier 5 amplifies the RF signal provided from the optical head 4 to generate digital data. The wobble decoder 9 extracts the wobble component from the digital data and uses the wobble component to generate the rotation control signal. In accordance with the rotation control signal, the spindle servo circuit 3 controls the spindle motor 2 so that the optical disc 32 is rotated at a constant linear velocity. The ATIP decoding circuit 10 decodes the ATIP using the wobble component and extracts the ATIP address of the absolute time information in the ATIP.

When the transmission rate of the data provided from the personal computer 31 is slower than the transmission rate of the data recorded in the optical disc 32 (write speed), that is, when the transmission rate of the data provided to the buffer 13 is slower than that of the data output from the encoder 14, the amount of data stored in the buffer memory 13 decreases. When the buffer underrun determination circuit 20 determines that a buffer underrun error may occur in the buffer memory 13, the recording control circuit 21 controls the interrupt/restart circuit 43 so that, before the occurrence of a buffer underrun in the buffer memory 13, the address memories 47, 48 are accordingly provided with the interrupt signal and the output of recording data from the encoder 14 is interrupted. In response to the interrupt signal, the address memories 47, 48 store the data address of the buffer memory 13. In other words, the address memory 47 stores the buffer memory address of the data read from the buffer memory 13 when receiving the interrupt signal. The address memory 48 stores the ATIP address of the ATIP decoding circuit 10 when receiving the interrupt signal.

When the output of the recording data from the encoder 14 is interrupted, the transmission of the drive signal from the laser drive circuit 16 to the optical head 4 is impeded. This stops the emission of the laser beam from the optical head 4 and interrupts the recording of data on the optical disc 32.

When the interrupt/restart circuit 43 outputs the interrupt signal, the sector of the data being output from the encoder 14 is recorded on the optical disc 32. It is preferred that the interrupt signal of the interrupt/restart circuit 43 be output at times between sectors of the recording data. The interrupt/restart circuit 43 stores in the memory 17 the voltage data of the laser drive signal output from the laser drive circuit 16 when the recording is interrupted.

Subsequent to the recording interruption, the data provided from the personal computer 31 is stored in the buffer memory 13 via the interface 12. As the amount of data stored in the buffer memory 13 increases, the state in which a buffer underrun may occur no longer exists. When the buffer underrun determination circuit 20 determines that buffer underrun is not likely to occur, the recording control circuit



21 controls the access control circuit 19 and the system control circuit 22 to perform data reproduction in the recording restart mode.

When data reproduction is performed in the recording restart mode, the access control circuit 19 controls the head servo circuit 6. The head servo circuit 6 controls focusing, tracking, and sled feed of the optical head 4 to move the optical head 4 to a sector location that is prior by a predetermined number of sectors from the sector at which the recording interruption occurred. The optical head 4 then irradiates the laser beam from that sector location.

The interrupt/restart circuit 43 controls the laser drive circuit 16 so that a drive signal having a constant voltage is output from the laser drive circuit 16. This results in the optical head 4 irradiating the optical disc 32 with a relatively weak laser beam. The reflected laser beam reproduces the data recorded on the optical disc prior to the recording interruption, and the optical head 4 outputs the RF signal. The RF signal is amplified by the RF amplifier 5 and converted to digital data. The decoder 7 decodes the digital data, extracts a pit clock from the digital data, and separates a subcode from the digital data. A subcode synchronizing signal is generated from the subcode. The subcode is decoded by the subcode decoding circuit 8 to generate the sub-Q data.

When data reproduction in the recording restart mode is started, the signal synchronizing circuit 42 switches the operational clock from the reference clock of the crystal oscillation circuit 18 to the reproduction clock of the decoder 7. The circuits 7-10, 12-16, 19-22 of the CD-R drive 1 are operated in accordance with the reproduction clock. By using the reproduction clock, the data recorded on the optical disc 32 prior to the recording interruption is accurately reproduced.

The recording control circuit 21 controls the interrupt/restart circuit 43 to instruct the encoder 14 to restart the output of the recording data. The encoder 14 goes back by a predetermined number of sectors from the data address of the buffer memory 13 at which the recording interruption occurred and starts reading data in sector units from that sector of the buffer memory 13. The encoder 14 adds a synch byte, a header, an EDC, and an ECC to the read data, performs the CIRC and EFM processes, and adds a subcode, which includes the sub-Q data, and the subcode synchronizing signal to the read data.

The drive signal of the laser drive circuit 16 is constant during data reproduction in the recording restart mode. In other words, the drive signal of the laser drive circuit 16 has a low voltage. Accordingly, laser irradiation does not affect the data recorded on the optical disc prior to the interruption.

The signal synchronizing circuit 42 controls the access control circuit 19 via the recording control circuit 21 and synchronizes the data recorded on the optical disc 32 with the recording data output from the encoder 14. In other words, the signal synchronizing circuit 42 controls the recording control circuit 21 and the access control circuit 19 so that the subcode synchronizing signal of the decoder 7 is synchronized with the subcode synchronizing signal of the encoder 14 and the sub-Q data of the subcode decoding circuit 8 is associated with the sub-Q data of the encoder 14.

The location detection circuit 45 compares the address of the data read from the buffer memory 13 with the address stored in the address memory 47 and activates the restart signal when the data address and the stored address are the same. The address stored in the address memory 47 is the address of the data read from the buffer memory 13 when the recording of data is interrupted.

The location detection circuit 46 compares the ATIP address of the ATIP decoding circuit 10 with the ATIP address stored in the address memory 48 and activates the restart signal when the ATIP address and the stored address are the same. The ATIP address stored in the address memory 48 is the ATIP address decoded by the ATIP decoding circuit 10 when the recording of data is interrupted.

When the restart signals of the location detection circuits 45, 46 are simultaneously activated, the retry determination circuit controls the interface 12, the access control circuit 19, and the system control circuit 22 via the recording control circuit 21. The signal synchronizing circuit 42 switches the operational clock of the system clock generation circuit 41 from the reproduction clock to the reference clock when recording is restarted.

Upon the restart of the recording, the address of the data read from the buffer memory 13 shifts to the address next to the address at which data recording was interrupted. Further, the address memory 48 and the location detection circuit 46 shift the sector location of the optical disc 32 irradiated by the laser beam to the sector location next to the sector location at which data recording was interrupted. In this state, the signal synchronizing circuit 42 synchronizes the recording data output from the encoder 14 with the data recorded on the optical disc 32. Accordingly, the data of the sector next to the sector at which data recording was interrupted is recorded upon the restart of the recording. In other words, sectors of data are recorded without any interruptions when restarting recording. This ensures the continuity of the recorded data while preventing the occurrence of a buffer underrun error.

The interrupt/restart circuit 43 activates the power of the laser beam emitted from the optical head 4 a predetermined time  $t$  before the time at which the restart of the recording operation becomes possible. More specifically, prior to the restart of the recording operation by the predetermined time  $t$ , the interrupt/restart circuit 43 controls the laser drive circuit 16 so that the laser drive circuit 16 provides the optical head 4 with a drive signal having a voltage corresponding to the data that was stored in the memory 17 when the recording operation was interrupted. This prevents the formation of a non-recording section on the optical disc 32. Thus, the recorded data has no interruptions.

In other words, if the recording data output by the encoder 14 has a high level when the recording operation is interrupted, although the voltage differs between track positions, the laser drive circuit 16 outputs a drive signal having a voltage that is several tens of times greater than that when data is reproduced. The laser power of the optical head 4 when the optical recording operation is interrupted is thus several tens of times greater than that when the reproduction operation is being performed. However, the power of the laser beam of the optical head 4 cannot be activated instantaneously to a level that is several tens of times greater than that of the reproduction operation. Accordingly, a certain amount of time is necessary to activate the power of the laser beam. That is, when activation the power of the laser beam of the optical head when restarting the recording operation, a certain length of time is required for the laser power to reach the desired level. Such delay forms a non-recording section on the optical disc 32 and interrupts the recorded data.

With reference to FIG. 2(a), a laser beam 101 is emitted against the surface of a recording medium 100. This results in reaction of a dye at the irradiated area and records data. In the example of FIG. 2(a), the laser beam 101 is intermit-



tently emitted against a section **102** of the recording medium **100** in accordance with the values "1" and "0" of the recording data to form a data section having a predetermined pattern. When the recording is interrupted at an interrupt position **103** on the recording medium **100**, a data section **104** is not formed in the desired manner. In this case, recording is restarted from the interrupt position **103** by performing data reproduction in the recording restart mode from a predetermined address. Referring to FIG. 2(b), it takes about several microseconds to several tens of microseconds to increase the drive voltage of the laser drive circuit **16** at the interrupt position **103** to a level equal to that when the interruption occurred. Hence, during this delay period, the intensity of the emitted laser beam **101** is low and a section **105** at which the dye does not react is formed on the recording medium **100**. Although the insufficient emission section **105** illustrated in FIG. 2(b) is short, several microseconds correspond to more than one hundred pulses of a clock. A synchronizing pattern allocated to the beginning of a frame is data of successive zeros or ones. In the synchronizing pattern, zeros or ones continue for 11 clock pulses. The insufficient emission-section **105** is about ten times longer than the synchronizing pattern. Accordingly, the insufficient emission section **105** may cause the reading of data to be unsatisfactory.

In the present invention, at a time that is earlier than the restart of the recording operation by the predetermined time  $t$ , the drive signal voltage is set to the level that existed when the recording interruption occurred. This increases the laser power of the optical head **4**. The predetermined time  $t$  corresponds to the time period required for activating the power of the laser beam. In other words, referring to FIG. 2(c), the laser power is activated at a section **106** that includes a location corresponding to the predetermined time  $t$  prior to the interruption position **103** of the recording medium **100**. Thus, the laser power reaches a sufficient level at the interrupt position **103**, and the desired data is recorded in a continuous manner on the section **104**.

This procedure permits the recording operation to be restarted when the laser beam has the same power as when the recording operation was interrupted. This prevents the formation of a non-recording section on the optical disc **32**. Thus, the recorded data has no interruptions.

Instead of setting the laser power of the optical head at the level that existed when the interruption occurred, the laser power may be set at a level that is sufficiently high. In other words, if the drive signal voltage is set at a sufficiently high level, the laser power may be decreased to the required level within a short period of time when restarting the recording operation. This eliminates the need for the memory **17**. However, if the laser power is set too high, the recording pits formed on the recording layer of the optical disc **32** may be burned out. Accordingly, it is preferred that the laser power of the optical head **4** be set at a level that does not burn out the recording pits.

When the two restart signals of the location detection circuits **45**, **46** are not synchronously activated (when the two restart signals are activated at different times), the retry determination circuit **44** repeatedly perform data reproduction in the recording restart mode until the two restart signals are synchronously activated. In other words, if an external disturbance occurs for one reason or another (e.g., the application of an external impact to the CD-R drive), the elements **2-22** of the CD-R drive **1** may function erroneously such that the two restart signals are not synchronously activated. Thus, the retry determination circuit **44** repeats data reproduction to avoid the influence of an external

disturbance. If the two restart signals of the location detection circuits **45**, **46** are always simultaneously activated, the retry determination circuit **44**, the location detection circuit **45**, and the address memory **47** may be deleted.

As shown in FIG. 3, the laser drive circuit **16** includes two memories **17**, **202**, two power sources **201**, **203**, two switches **204**, **205**, and an AND circuit **206**.

The memory **17** stores write voltage data, which corresponds to the write laser power. The power source **201** generates the write laser power in accordance with the write voltage data stored in the memory **17**. The power source **203** generates read laser power in accordance with read voltage data stored in the memory **202**. The AND circuit **206** receives the interrupt/restart signal and a mode switching signal for switching between a write mode and a read mode and outputs the switching signal of the switch **204**. The level of the mode switching signal is high during a write mode and low during a read mode. The interrupt/restart signal is normally high.

During the write mode, the mode switching signal output by the AND circuit **206** is high. Thus, the switch **204** selects the power source **201**. When an output signal of the encoder **14** is high, the switch **205** selects the output of the switch **204**, provides the optical head **4** with the write laser power of the power source **201**, and emits the laser beam against the recording medium. When the output signal of the encoder **14** is low, the switch **205** is switched to a predetermined voltage  $L$ .

When recording is interrupted and the interrupt/restart signal is shifted to a low level, the switch **204** is connected to the power source **203** and the output of the encoder **14** is stopped. Accordingly, the drive signal provided to the optical head **4** has a low voltage in correspondence with the read voltage data. This temporarily sets the read mode.

In a first method for activating the laser power provided from the power supply **201** before recording is restarted, the power source **201** is activated at a predetermined time  $t$  before recording is restarted. For example, during data reproduction in the recording restart mode, the power source **201** is activated when the read address or the address of the buffer memory **13** matches an address that is a predetermined number of addresses prior to that stored in the address memories **47** or **48**.

In a second method for increasing the laser power before recording is restarted, the restart/interrupt circuit **43** causes the interrupt/restart signal to go high to restart writing when the read address or the address of the buffer memory **13** matches an address prior to that stored in the address memories **47** or **48** by a predetermined number of addresses  $x$ . In this case, the optical head **4** emits the laser beam against the section on which data has already been recorded. However, since the laser power is still low, the data on the recorded section is not rewritten. When the output of the power source **201** increases and the write laser power becomes sufficient, the emitted laser beam reaches the interrupt position **103** of the recording medium **100**. Accordingly, the predetermined address number  $x$  is set to correspond with the predetermined time  $t$  required for activating the laser power to the required level.

The address of the interrupt position **103** may be stored in the address memories **47**, **48** to advance the recording operation from the interrupt position **103**. Alternatively, an address that is a predetermined number of addresses prior to that of the interruption position **103** may be stored in the address memories **47**, **48**.

It is preferred that the predetermined time  $t$  be set experimentally in accordance with the laser power increasing



characteristic of the optical head 4. For example, the predetermined time  $t$  may be set several microseconds to several tens of microseconds prior to the restart of the recording operation. The predetermined time  $t$  is determined based on the pulse count of the operational clock of the CD-R drive 1. When the recording speed of the CD-R drive 1 is set to  $4\times$  or  $8\times$ , the system clock generation circuit 41 generates an operational clock having a high frequency. Accordingly, during high speed operations, the pulse count of the operational clock and the predetermined address number  $x$  must be increased in accordance with the operational speed so that the laser power activation of the optical head 4 is in time for the restart of the recording operation.

The memory 17 is preferably an eight bit (the bit number of the write voltage data) latch circuit formed by flip-flops. The write voltage data latched by the latch circuit is held when the recording is restarted until the laser power is activated to a sufficient level. In other words, the write voltage data held by the latch circuit is not corrected when the recording is restarted until the laser power increases to a sufficient level.

FIG. 4(a) is a schematic view showing a sector of the optical disc 32. FIG. 4(b) is a diagram illustrating the addresses of the buffer memory 13. Sectors  $S_{n+1}$ ,  $S_n$ ,  $S_{n-1}$ ,  $S_{n-2}$  . . . ,  $S_{n-m}$  shown in FIG. 4(a) are respectively associated with addresses  $A_{n+1}$ ,  $A_n$ ,  $A_{n-1}$ ,  $A_{n-2}$ , . . . ,  $A_{n-m}$  shown in FIG. 4(b).

During recording, data is read from the buffer memory 13 in the order of addresses  $A_{n-m}$ , . . . ,  $A_{n-2}$ ,  $A_{n-1}$ ,  $A_n$ , and the recording data encoded by the encoder 14 is recorded on the optical disc 32 in the order of sectors  $S_{n-m}$ , . . . ,  $S_{n-2}$ ,  $S_{n-1}$ ,  $S_n$ . For example, if the buffer underrun determination circuit 20 determines during the recording of data that a bus underrun may occur at address  $A_n$ , the data of sector  $S_n$ , which is associated with address  $A_n$ , is recorded. However, the recording of data is interrupted from the sector  $S_{n+1}$ , which is associated with address  $A_{n+1}$ .

When the recording of data is interrupted, address  $A_n$  is stored in the address memory 47, and the address of the ATIP decoded from the data recorded at sector  $S_n$  is stored in the address memory 48. Afterward, when the buffer underrun determination circuit 20 determines that a buffer underrun is no longer likely to occur, data reproduction in the recording restart mode is commenced from sector  $S_{n-m}$  by going back from sector  $S_n$ , at which recording was interrupted, by a predetermined number of sectors (in this case,  $m$  sectors).

When data reproduction is commenced, data is read from the buffer memory 13 from address  $A_{n-m}$  by going back from address  $A_n$ , at which recording was interrupted by a predetermined number of addresses ( $m$  addresses). The read data is encoded into recording data by the encoder 14.

The signal synchronizing circuit 42 synchronizes the recording data output from the encoder 14 with the data recorded on the sectors  $S_{n-m}$  to  $S_n$  of the optical disc 32. Then, when the address of the data read from the buffer memory 13 matches the address  $A_n$  stored in the address memory 47, the restart signal of the location detection circuit 45 is activated. When the address of the ATIP decoded by the ATIP decoding circuit 10 matches the ATIP address of the sector  $S_n$  stored in the address memory 48, the restart signal of the location detection circuit 46 is activated. When the two restart signals of the location detection circuits 45, 46 are simultaneously activated, the retry determination circuit 44 restarts the recording of data from sector  $S_{n+1}$ , which is next to the sector  $S_n$  at which data recording was interrupted.

It is preferred that the predetermined sector number ( $m$  sectors) be sufficient for obtaining time period  $T1$ , which is required for the spindle serve circuit 3 to control the spindle motor 2 and the head servo circuit 6 to control the optical head 4, and time period  $T2$ , which is required for synchronization by the signal synchronizing circuit 42. For example,  $m$  is set at 10 to 30. The time periods  $T1$ ,  $T2$  increase as the recording speed of the CD-R drive 1 becomes higher, for example, as the recording speed increases from  $4\times$  to  $8\times$ . Accordingly, it is preferred that the predetermined sector number be increased as the recording speed increases.

In the present invention, the power of the laser emitted against the recording medium is activated before restarting the recording operation. Thus, the laser beam emitted when the recording operation is restarted has a sufficient power level. Accordingly, non-recorded sections are not formed on the recording medium. This prevents interruptions in the recorded data.

Further, the interrupt/restart circuit 43 instructs the restart of the recording before the read position of the recording medium reaches the interruption position 103. Thus, the emitted laser beam has a sufficient power level for writing from the interruption position. Accordingly, non-recorded sections are not formed on the recording medium. This prevents interruptions in the recorded data.

Additionally, the power level of the laser beam at the time point when the recording operation is interrupted is stored in the memory 17. The laser power level is activated beforehand based on the power level stored in the memory 17. Accordingly, a laser beam having the optimal power level is emitted. This prevents the formation of non-recorded sections on the recording medium.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the present invention may be embodied in the following forms.

(1) The present invention may be applied to a data recorder employing the constant angular velocity (CAV) method. In such case, a clock synchronized with the wobble component, which is extracted by the wobble decoder 9, is generated and used as the operational clock during the recording of data.

(2) The access control circuit 19, the buffer underrun determination circuit 20, the recording control circuit 21, and the system control circuit 22 may be replaced by a microcomputer that includes a CPU, a ROM, and a RAM. In other words, the function of each circuit may be achieved by having a microcomputer perform various operations.

(3) The present invention may be applied to a data recorder (e.g., CD-RW drive, MD drive) that uses a rewritable recording medium (e.g., CD-RW standard optical disc, MD standard optical disc). In such case, the occurrence of a buffer underrun error is prevented. This decreases the time required for the recording of data.

(4) The present invention may be applied when data writing is interrupted due to the displacement of the optical head 4. Data writing to the optical disc 32 is also interrupted when the relative position between the optical head 4 and the optical disc 32 is offset due to a physical impact or a mechanical deficiency. In such case, the present invention may be applied to restart the writing of data from the interrupted position. For the restart of data writing, a mechanism for determining the displacement of the optical head 4 may be used in lieu of the buffer underrun determination circuit 20. The displacement determination mechanism may be formed by a vibration sensor, which detects external



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vibrations of the optical disc 32, a detection circuit, which detects a tracking error of the optical head 4 relative to the optical disc 32, or the like.

The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

The invention claimed is:

1. A controller for controlling interruption and restarting data writing to a recording medium, wherein writing the data stored in a buffer memory to the recording medium or reading the written data from the recording medium is performed by selectively providing an optical head performing a laser irradiation with a write laser power source or a read laser power source, the controller comprising:

an address memory for storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted, each address indicating a location where the writing interruption occurred; and

a restart circuit for generating an instruction for restarting the writing of data to the recording medium by changing the power source provided to the optical head from the read laser power source to the write laser power source based on the address stored in the address memory while reading the written data from the recording medium by providing the optical head with the read laser power source,

wherein the restart circuit generates an instruction for setting the voltage of the write laser power source to a write level prior to generating the instruction for restarting.

2. The controller of claim 1, wherein the controller generates an instruction for interruption when it is determined that a buffer underrun is likely to occur based on the amount of data stored in the buffer memory.

3. A controller for controlling interruption and restarting data writing to a recording medium, wherein writing the data stored in a buffer memory to the recording medium or reading the written data from the recording medium is performed by selectively providing an optical head performing a laser irradiation with a write laser power source or a read laser power source, the controller comprising:

an address memory for storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted, each address indicating a location where the writing interruption occurred; and

a restart circuit for generating an instruction for restarting the writing of data to the recording medium by

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changing the power source provided to the optical head from the read laser power source to the write laser power source based on the address stored in the address memory while reading the written data from the recording medium by providing the optical head with the read laser power source,

wherein the restart circuit generates the instruction for restarting before the location of the data read from the recording medium reaches the interruption location.

4. The controller of claim 3, the timing that the restart circuit generates the instruction for restarting is set in accordance with the time required for setting the voltage of the write laser power source to a write level.

5. The controller of claim 3, wherein the controller generates an instruction for interruption when it is determined that a buffer underrun is likely to occur based on the amount of data stored in the buffer memory.

6. A controller for controlling interruption and restarting data writing to a recording medium, wherein writing the data stored in a buffer memory to the recording medium or reading the written data from the recording medium is performed by selectively providing an optical head performing a laser irradiation with a write laser power source or a read laser power source, the controller comprising:

an address memory for storing at least one of an address of the recording medium and an address of the buffer memory when the writing of data to the recording medium is interrupted, each address indicating a location where the writing interruption occurred;

a memory for storing data corresponding to a write level of the voltage of the write laser power source when data writing to the recording medium is interrupted; and

a restart circuit for generating an instruction for restarting the writing of data to the recording medium by changing the power source provided to the optical head from the read laser power source to the write laser power source based on the address stored in the address memory while reading the written data from the recording medium by providing the optical head with the read laser power source.

7. The controller of claim 6, wherein the restart circuit generates an instruction for setting the voltage of the write laser power source to a write level prior to generating the instruction for restarting.

8. The controller of claim 6, wherein the controller generates an instruction for interruption when it is determined that a buffer underrun is likely to occur based on the amount of data stored in the buffer memory.

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